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Technical Report ARCCD-TR-02003

120-mm TARGET PRACTICE CONE STABILIZED DISCARDING SABOT WITH TRACER (TPCSDS-T) M865 (E3) REWORK REPORT (POP-RIVET DESIGN)

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U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

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14. ABSTRACT
In 1998 to 1999, a major redesign of the M865 adapter and insert cover interface was undertaken. A snap-joint method was adopted and put into the field for testing. A few months later, reports of failure were reported and a team was brought together to investigate the problem. The primary focus of the group was to reinforce the joint configuration without disassembling the cartridge, insuring chemical compatibility, and meeting all ballistic requirements. The team came up with three different solutions for field fix rework: (a) pop rivets; (b) foam fill, and (c) pool of epoxy. The foam design was the number one choice of the team, but the pop rivets had lower overall risk. The pop-rivet design was chosen over the others because of its low maintenance and symmetry. The design consisted of 15 countersunk pop rivets equally spaced around the circumference of the case adapter. The pop-rivet design was put through the entire screening process and the scenario provided adequate axial support, while passing all of the qualification testing. Suspended cartridges could now be reworked and reissued to the stockpile.

15. SUBJECT TERMS

120-mm tank ammunition cartridge

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INTRODUCTION/BACKGROUND

Production of the 120-mm M865 target practice cone stabilized discarding sabot with tracer (TPCSDS-T) began in 1985 using the "bolt on cover" (BOC) design that was taken directly from the Rheinmetall technical data package (TDP). In 1988, per Department of the Army (DA) direction, 25,000 M865's were procured from each of the prime contractors using a "Form, Fit and Function Specification." Alliant Tech Systems (ATK) introduced the "glue on cover" (GOC) on their 25,000 quantity. Subsequently, because of the excellent performance of those rounds and the substantial cost savings, the GOC was included as an alternate in the government TDP. General Dynamics Ordnance and Tactical Systems (GD-ODTS) formally Primex Technologies Inc., also chose to adopt the GOC, but began to experience target impact dispersion (TID) problems that they believed were directly attributable to the GOC design and they chose to return to the BOC. Subsequently, with the transition of ATK's M865 projectile production from Valentec to Ferrulmatic, ATK also began to experience TID problems, and by 1995 both prime contractors had returned to the BOC design.

In 1998-1999, a major redesign of the M865 adapter and insert cover interface was implemented along with a change in the cartridge case paint system from polyurethane to epoxy. The snap-joint attachment method was similar to that used on the 120-mm M829 and M829A1 armor piercing fin stabilized discarding sabot with tracer (APFSDS-T) kinetic energy (KE) tactical rounds, and the change in paint system reflected a change made to all tactical rounds several years earlier to improve handling durability. The cartridges were subjected to and passed product qualification tests including sequential rough handling (ITOP 4-2-602, page 9) and sequential vibration (secure cargo and rack) tests (ITOP 1-2-601 Sec. B and C). Shortly after release of these new rounds (April 1999), field problems were encountered with separation of the projectile from the cartridge case at the snap joint.

By May 2000, a modification consisting of a longer nylon insert and approximately 24 g of green epoxy was introduced to provide a more durable projectile to cartridge case attachment. Initial field experience with the modified rounds in October 2000, indicated that the joint strength issue was resolved, but there had been a number of instances of chambering failures due to large pieces of adapter bonded to green epoxy (fig. 1) adhering to an epoxy paint coating in the forward area of the cannon chamber, called chamberage. The residue issue was serious enough to warrant establishing a team to investigate the problem. By June 2001, a modification consisting of half the amount of epoxy (approximately 12 g of green epoxy) was introduced to still provide a durable projectile to cartridge case attachment, which also eliminated the residue in the gun tube issue. After a thorough investigation by the team, a report was issued titled "Report of Barrel Residue Investigation Team," dated January 25, 2002.

FIELD FIX REWORK

Approximately 140,000 rounds of the original snap-joint design were suspended from use, most where in storage at Iowa Army Ammunition Plant (IAAP), but approximately 42,000 where in storage in forts in Germany and the United States. The field fix rework procedure had to encompass a design that would reinforce the original case adapter/insert cover joint configura-tion. The design would increase the axial strength beyond that currently provided by the adapter lip material without the need for disassembly of the cartridge, while allowing for complete chamberability, insuring component chemical compatibility with propellant and meeting ballistic residue requirements.

General

On 16 November 2001, a brainstorming session was conducted with U.S. Army Armament Research, Development and Engineering Center (ARDEC) and Program Manager-Tank and Medium-caliber Armament systems (PM-TMAS) personnel with representatives from ATK and GD-ODTS connected by telephone. Many of the ideas generated in that session carried over into the session held on 05 December (reference report RN-001222-001 titled "M865 Field Fix Rework and Interim Residue Fix Brainstorming Session," dated 22 December 2001). The team concluded the following three concepts should be pursued for the field fix rework.

- Pop rivets
- Foam fill
- Pool of epoxy

The foam design was the number one choice of the brainstorming team; however, the pop rivets had a lower overall risk because of supporting test data.

During the demonstration phase of the program three types of mechanical rework fixes were simultaneously tested along with the foam fill and pool of adhesive designs. The three mechanical designs were 18 plastic countersunk screws (fig. 2), 18 plastic countersunk pop rivets (fig. 3), and 15 plastic countersunk pop rivets (fig. 4). The 15 pop-rivet design was initiated after the 18 plastic rivets and screws designs were initially tested with excellent results. This 15 pop-rivet design was chosen because of economic (less rivets and machining) and symmetry (less chance of the rivets to interfere with the slots on the insert cover) attributes.

Plastic Countersunk Screw Design

This design was pursued by GD-ODTS and reinforced the existing joint by inserting a series of nylon screws through the case adapter/insert cover interface equally spacing each fastener around the cartridge circumference (fig. 2). This required the drilling, tapping, and counter-sinking of the case adapter and insert cover interface (fig.5) to a controlled depth then applying epoxy into each hole prior to inserting nylon countersunk screws for a below flush installation. The tapping operation was labor-intensive requiring additional fixtures and not very cost effective.

Plastic Countersunk Pop Rivet Design

This design reinforced the existing joint by inserting a series of nylon pop rivets through the case adapter/insert cover interface equally spacing each fastener around the cartridge circumference (fig. 4). This required the drilling and countersinking of the case adapter and insert cover interface (fig.6) to a controlled depth then installing modified pop rivets. The design required a drill fixture to consistently position the holes in their exact location (fig. 7). The modification to the pop rivet (figs. 8 and 9) consisted of machining the head to allow for countersinking and a below flush installation. The modification to the pop rivet was less costly when compared to the tapping operation of countersunk screw design.

Foam Fill Design

This design was initiated by ATK and pursued by ARDEC requiring the drilling of a hole in the case adapter and injecting urethane foam into the ullage area between the case adapter and slotted conical fin to stabilize the projectile. The design provided the projectile with additional support in fin area (fig. 10). This design seemed to provide a solution to the problem, but encountered large negative delta pressures, which could not be resolved (fig. 11). To insure the negative delta pressures were inherent of the foam fill design, 36 rounds were modified to test the foam fix concept.

Twelve rounds were modified using the original foaming method. Foam was injected into the loaded cartridges through the pressure port in the adapter until all the ullage appeared to be filled. The hole was then taped over using duct tape.

Twelve rounds were modified using a "pre-cured" foaming method. The propellant was downloaded and the cartridge cases were separated from the adapters. The propellant for each round was put into a separate bag and marked so that each round would have the same charge weight that it started with. Each adapter was filled with a 1-in. layer of foam. After curing for 24 hrs, new cartridge cases were glued to the adapters. The rounds were chambered tested to check for proper alignment. After allowing the foam to cure for another 12 hrs, the propellant was loaded back into the rounds.

Twelve rounds were modified using a "new and improved" technique developed at IAAP by ATK, GD-ODTS, and ARDEC. The process used was:

- Drill three holes 9/16 in. in diameter, 120 deg apart, 7/8-in. down from the top of the adapter
- Hand shake round to level the propellant bed
- Push the propellant bag down with a dowel rod through all three holes
- Tape each hole with 1 to 2 layers of masking tape
- Poke through tape on one hole with small dowel rod
- Insert foam can straw through hole in tape, place straw to the right of the core and as far back as possible
- Fill right side with foam for 5 sec, while pulling straw back towards hole

Pool of Epoxy Design

This design required the drilling of a hole in the case adapter and inverting the cartridge (nose down) during epoxy installation. The epoxy used was a two-part epoxy consisting of Epon 828 and Versamid 140. The epoxy was pooled on the rear of the sabot and onto the adapter. In addition, a method had to be developed to keep the propellant bag out of the way during epoxy installation (fig. 12). The design contained additional concerns. Since there was an existing problem with epoxy residue on the current production design, this design, although pursued, was not adopted.

Demonstration Test

A demonstration test of the three designs: foam, plastic pop-rivet, and pool of epoxy (fig. 12) was successfully completed at Aberdeen Proving Ground (APG). Ten rounds each were subjected to a TID ballistic test at ambient temperature.

Verification Testing

Two designs, foam and pop rivet, were selected for verification testing at APG. The pool of epoxy design was eliminated due to production and residue concerns. Thirty rounds each were unsuccessfully subjected to a ballistic test at ambient, hot, and cold temperatures. An additional 20 rounds each were successfully subjected to transportation vibration, rough handling, and drop testing. The plastic pop rivet and the foam design failed the TID requirement at cold and negative delta pressure requirement at hot, respectively. The TID problem may have been a test anomaly because a similar problem was encountered with the control rounds. The control rounds were from the same lot previously used when preliminary testing for the pop-rivet design was conducted. The negative delta pressure problem was real; additional testing confirmed it.

The team initiated a go forwarded plan, which was approved by the Integration Team. The plan proposed was three fold. First, redo the TID test for the pop-rivet design. The test rounds would be shot alternating with the control rounds. Second, investigate and understand the negative delta pressure problem and modify the design and/or conduct additional ballistic testing to determine the extent of the problem.

Although many methods were used to install the foam verification tests indicated the foam design still had large negative delta pressures while the pop rivet design pressures were acceptable. Since the negative delta pressure issue could not be resolved the foam design was terminated and all effort was put into the pop rivet design.

Additional Screening

As part of the verification test, an additional screening was conducted. The screening consisted of rough handling and chambering/extraction tests in a M1A2 tank located at ARDEC. Basically, the cartridge was knocked about while loading and extracting five times in the process of checking for damage each time.

Pendulum Test

The pendulum test (fig. 13) was developed early on during the field fix rework program to provide a good initial screen for a design's level of robustness and anticipated performance during the user-loading test. The pendulum test is intended to simulate a side impact of the cartridge with an object and places a dynamic bending load on the projectile/adapter interface (fig. 14). This test depicts a worst-case scenario of what can happen to a cartridge when being handled within the turret of the tank.

Pendulum Test Description

The pendulum test provides a controllable side impact to the front of a projectile simulating dropping the front of the round on the breechblock during chambering or otherwise hitting the projectile during unpackaged handling. The pendulum test impact point is 3.75 in. from the tip of the core (fig. 15) and the distance from the pivot point to the tip of the core is 77 in. (fig. 15). The cartridge is suspended upside down by the case base then pulled back and released to impact a steel angle iron on a wall (fig. 16). The distance of the swing is measured diagonally from the wall intended impact to the core intended impact. The test consists of a series of swings starting at 2 ft then going to 3 ft, 4 ft, etc. (fig. 16). The test is stopped when the joint separates (fig. 17) to a point where it does not look like it chambers or the sabots become loose. The test is never conducted beyond 6 ft. The design that came apart in the field had only taken 3 ft to separate the case adapter from the insert cover not allowing the projectile to chamber.

User Loading Test

As part of the verification and qualification tests, the pop rivet and foam design cartridges were subjected to a user-loading test. The test was conducted at APG and consisted of Master Gunners rough handling, while loading and chambering/extracting the cartridges. The Master Gunner's would deliberately try to handle the round in a manner they would expect a very rough loader to do. The intent is not to see how hard they can bang the round, but rather expose the round to banging that it would expect to see in the field. Although the test was very subjective, it was a recommendation of what was acceptable for the M865E3 pop-rivet design.

Qualification Testing

Qualification testing for the M865E3 pop-rivet design was conducted at APG and consisted of sequential rough handling (SRH) tests and secured cargo vibration (SCV) tests with temperature conditioning. In addition, chamber and extraction tests, user-loading tests, and residue tests had to be conducted as part of the qualification testing. The SRH and SCV tests were conducted on the 3rd through the 7th of December 2001. The control rounds used were BOC as well as unmodified M865 cartridges. Summaries of dispersion, velocity, and pressure results are presented in tables 1 through 5.

As part of the user-loading test, a stationary users test (tank not moving) was conducted in which 15 rounds from all four designs were tested simultaneously. Two of the designs, optimum epoxy and reduced epoxy humiseal adapter, were part of the residue test. The other two designs, pop rivet and expanding foam were part of the field fix rework test. Two of the designs, foam and reduced epoxy/humiseal showed anomalies. The results were shown in figure 19.

The "rapid fire" residue test (fig.18) was designed by the Residue Team and conducted at APG during the March 2001 timeframe. The tests indicated residue was not an issue for the pop-rivet design.

The M865E3 pop-rivet design met all the requirements of the qualification tests with acceptable results.

CONCLUSION

Many of the designs recommended by the Brainstorming Team had merit, but the pop-rivet design proved to be the best scenario. The field fixing of the M865E3 target practice cone stabilized discarding sabot with tracer cartridges (fig. 21) by adding 15 nylon countersunk pop-rivets equally spaced around the circumference of the case adapter provided the projectile with adequate support to pass all qualification testing. This allowed the suspended cartridges at Iowa Army Ammunition Plant (IAAP) to be reworked and then reissued to the stockpile. The field modification to the existing cartridges could be accomplished without downloading or destroying any of the existing assets. Fixtures (fig. 7) and tooling (fig. 20) to facilitate the field modifications were developed by the U.S. Army Armament Research, Development and Engineering Center (ARDEC) and supplied to the contractor (IAAP) for implementation. The modified pop rivets (countersinking operation) were designed by ARDEC. ARDEC also developed a process to mold the pop rivets to final dimensions without any additional machining, therefore reducing costs. ARDEC is also supplying the pop rivets to IAAP.

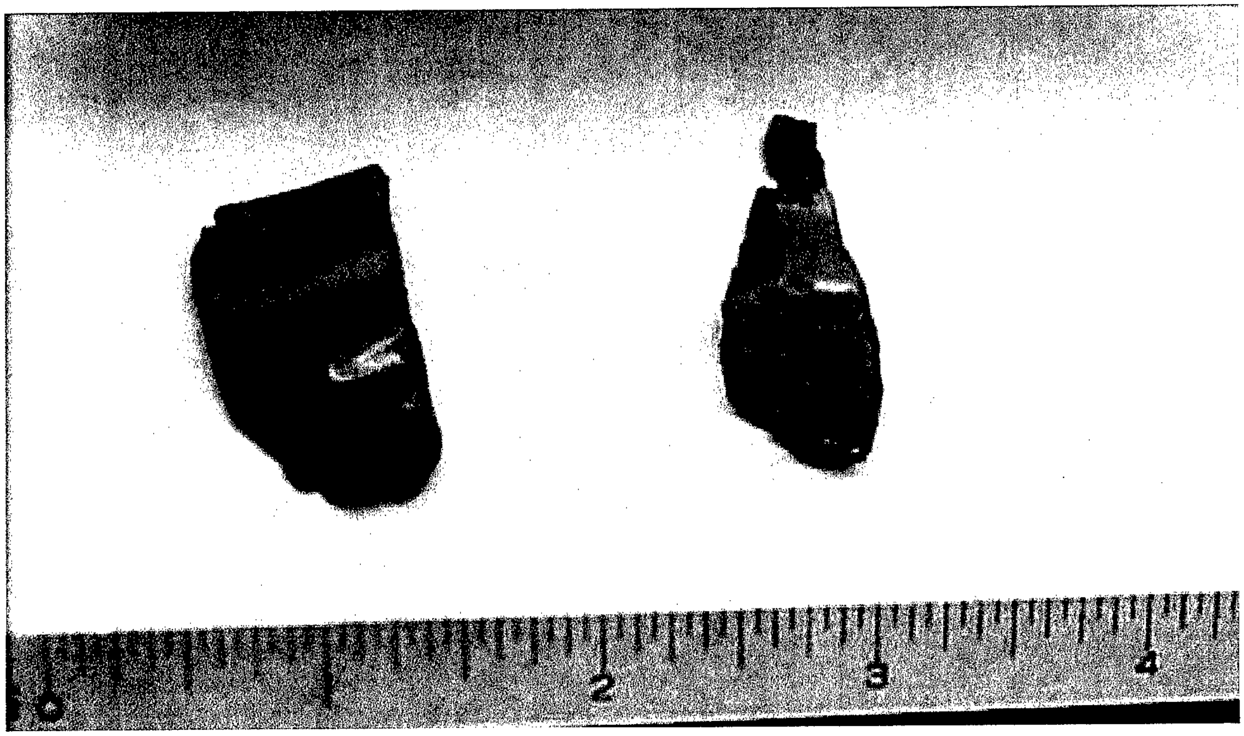

Figure 1
Green epoxy residue with adapter material attached

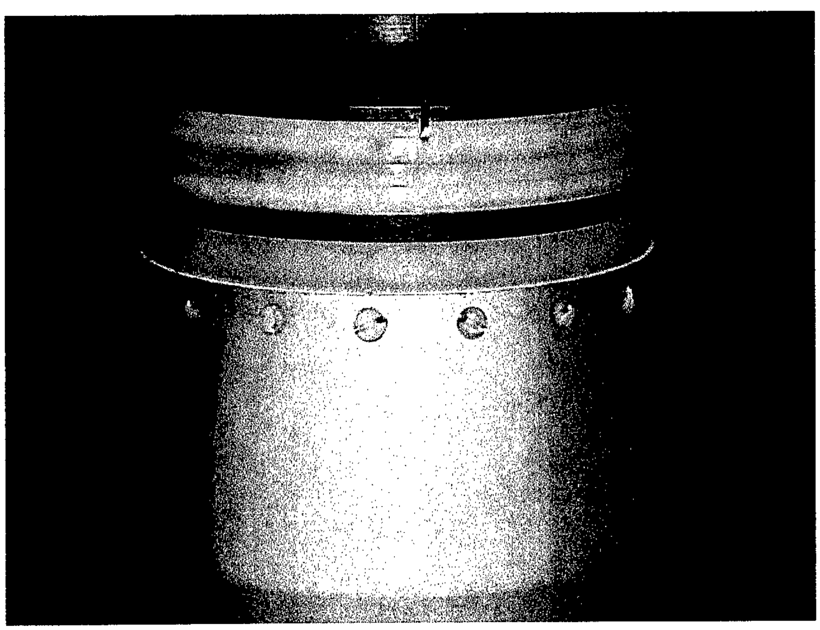

Figure 2
Eighteen setscrew design

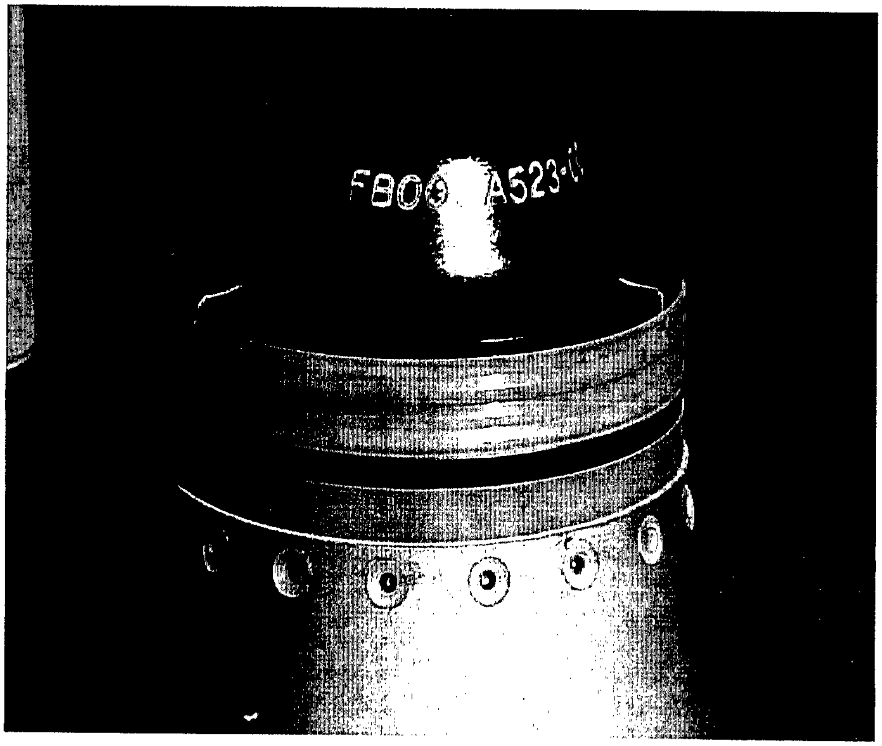

Figure 3
Eighteen pop-rivet design

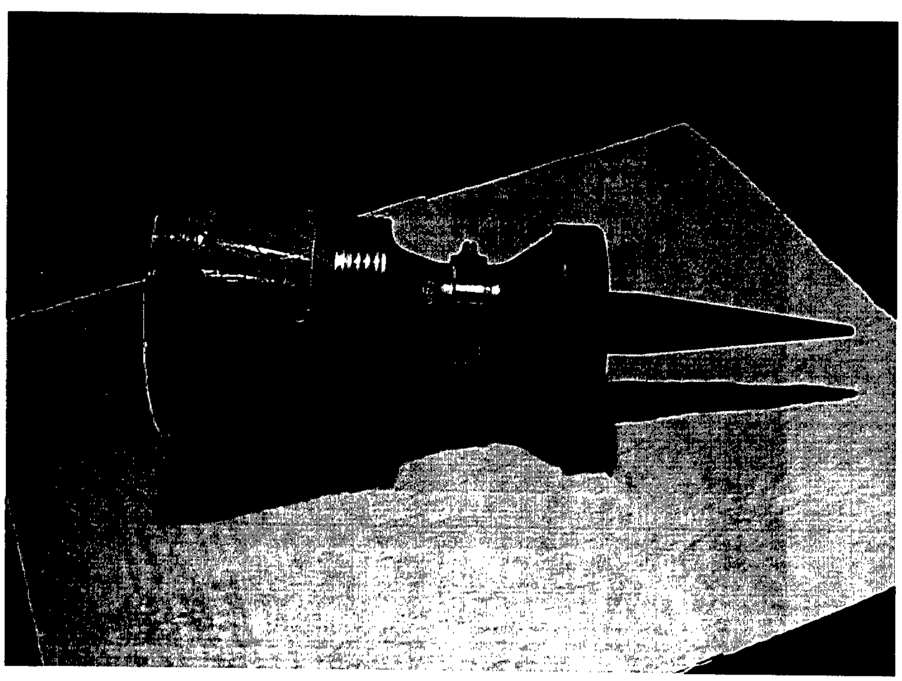

Figure 4
Plastic pop-rivet design

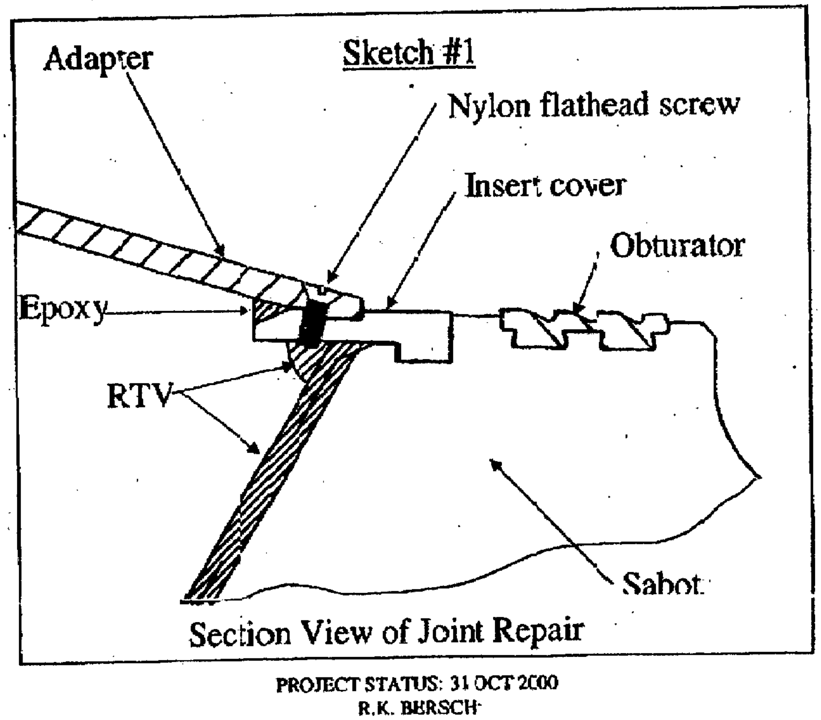

Figure 5
Case adapter and insert cover interface with setscrews

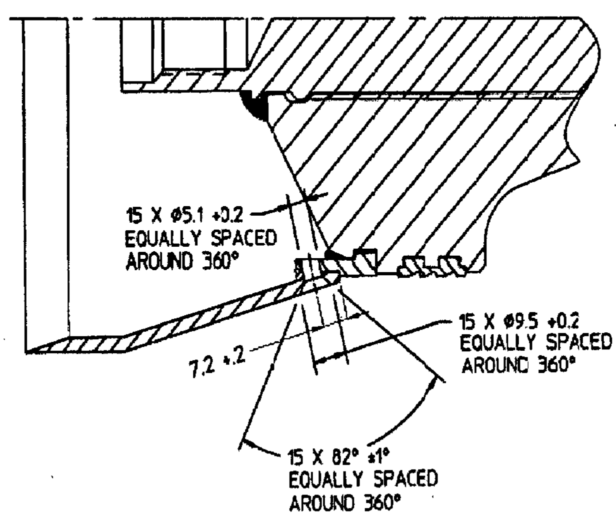

Figure 6
Case adapter and insert cover interface for pop rivets

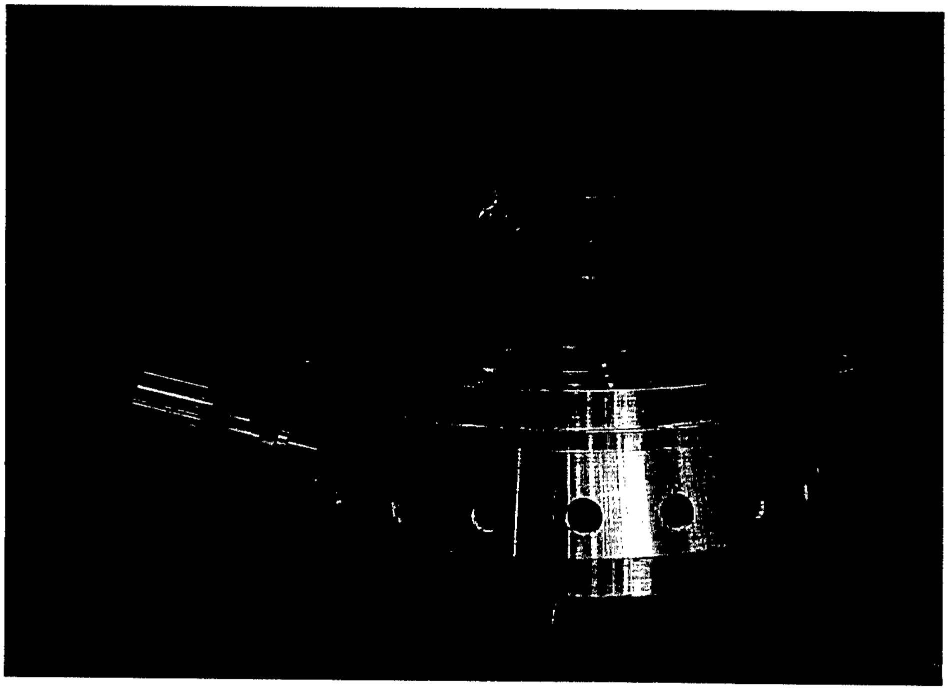

Figure 7
Positioning and drilling fixture (pop-rivet design)

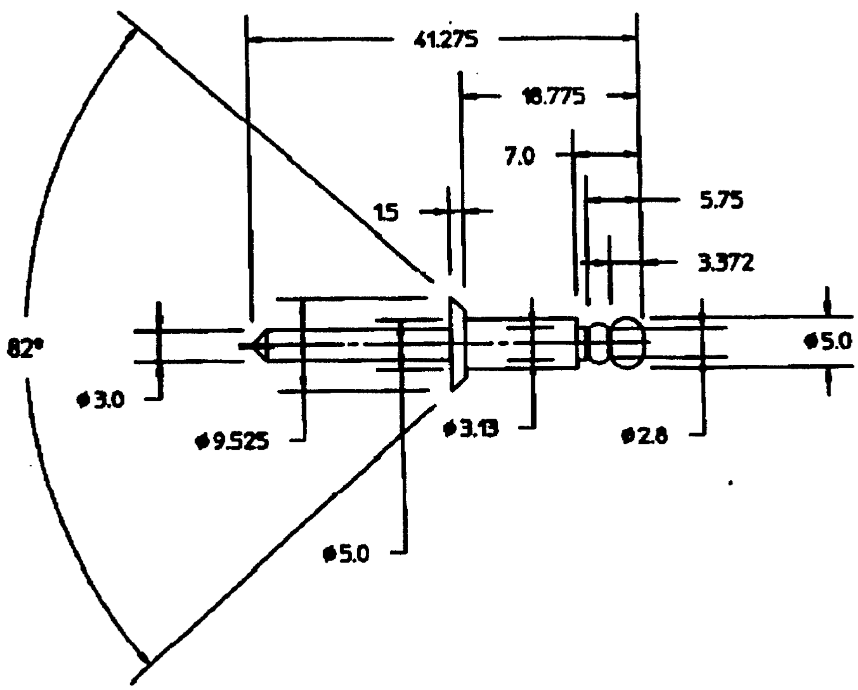

Figure 8
Modification to pop rivet schematic

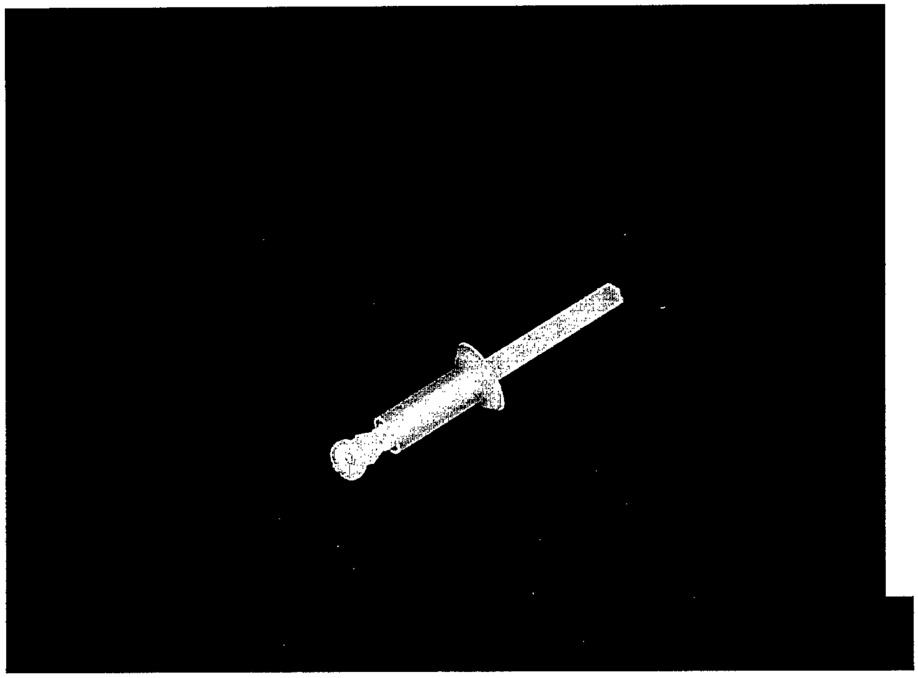

Figure 9
Modification to pop rivet

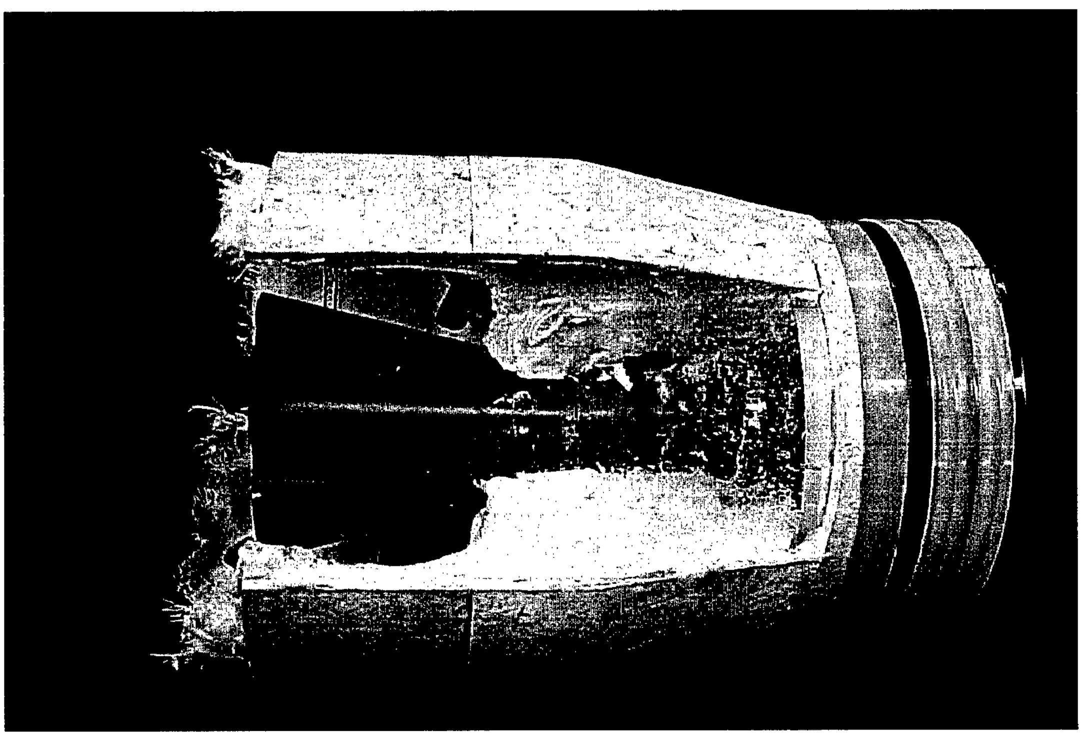

Figure 10
Foam fill design

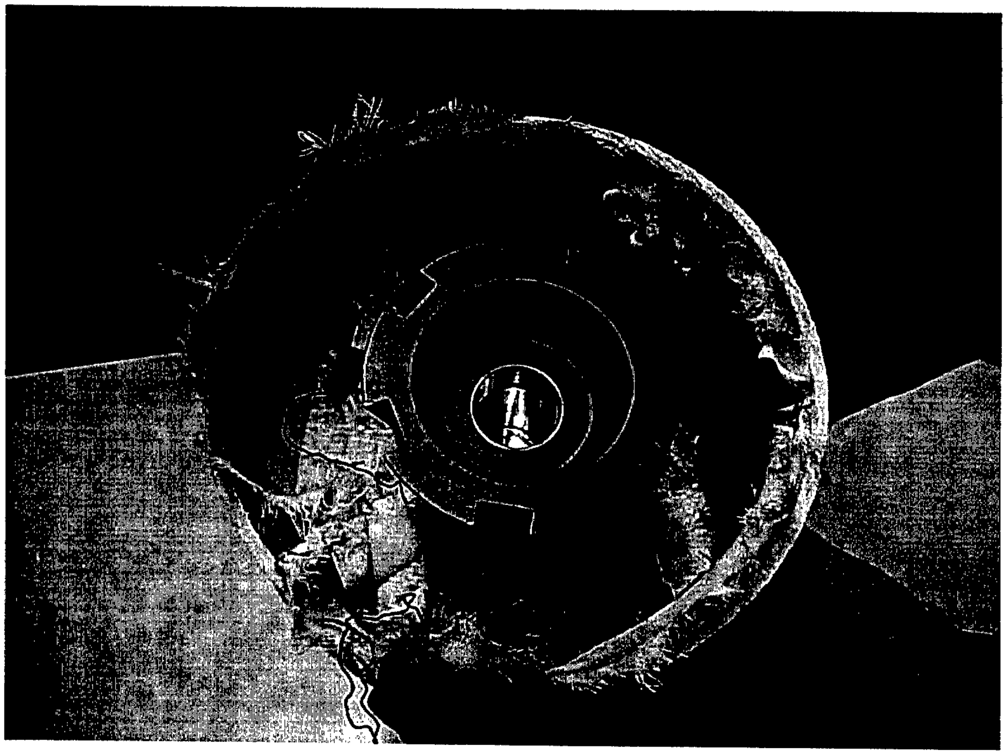

Figure 11
Foam fill design (rear view)

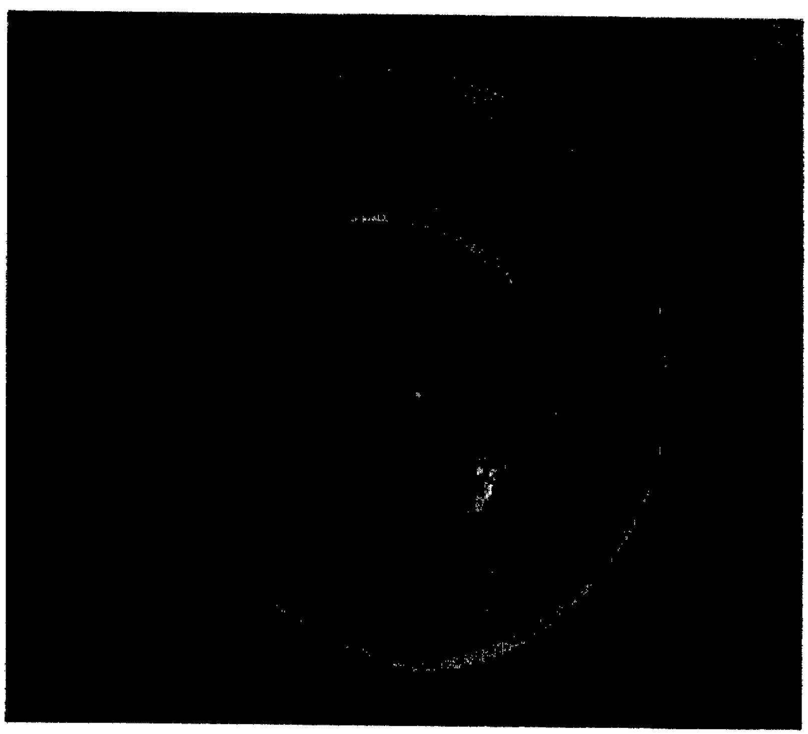

Figure 12
Pool of epoxy design

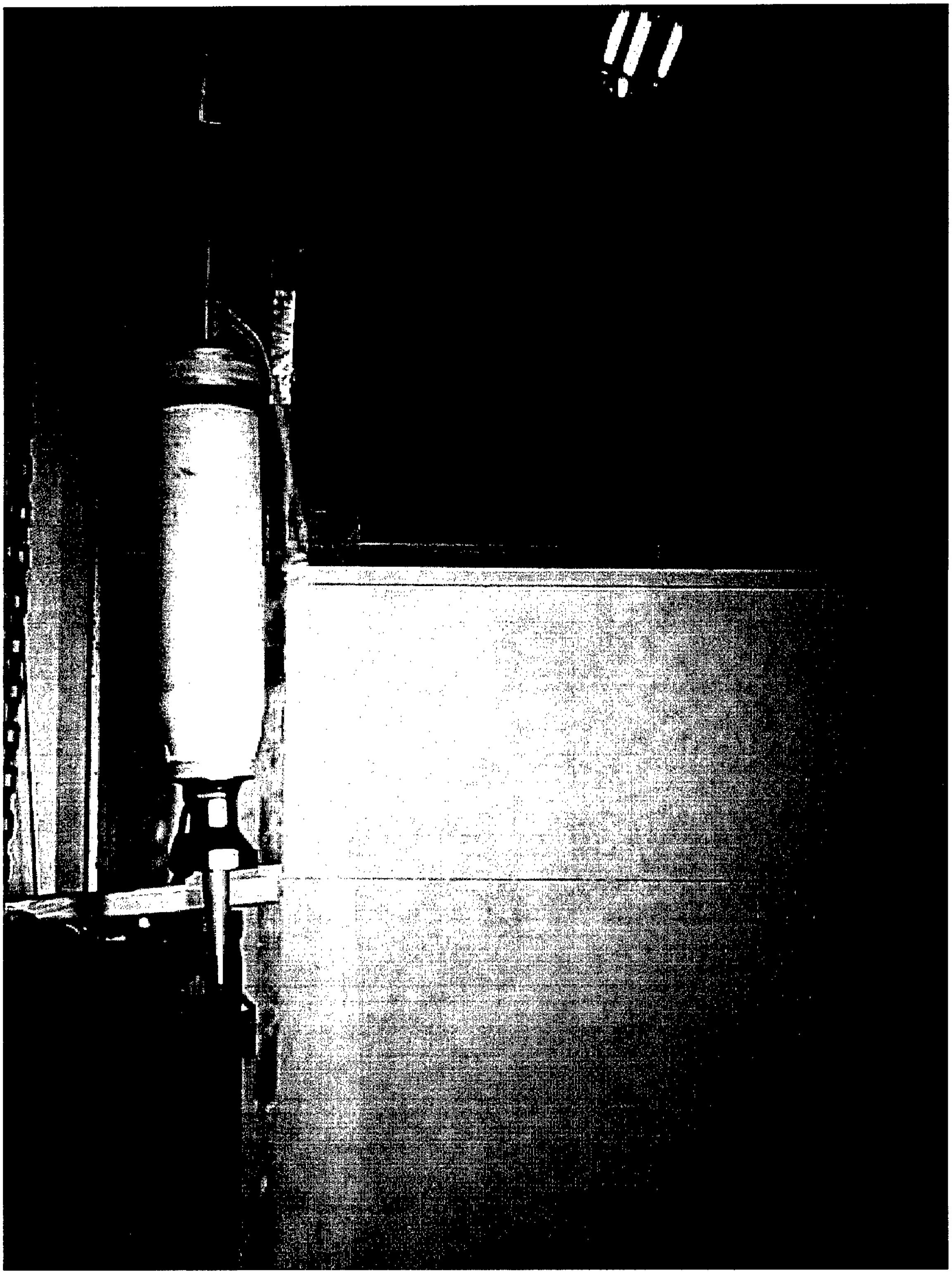

Figure 13
Pendulum test

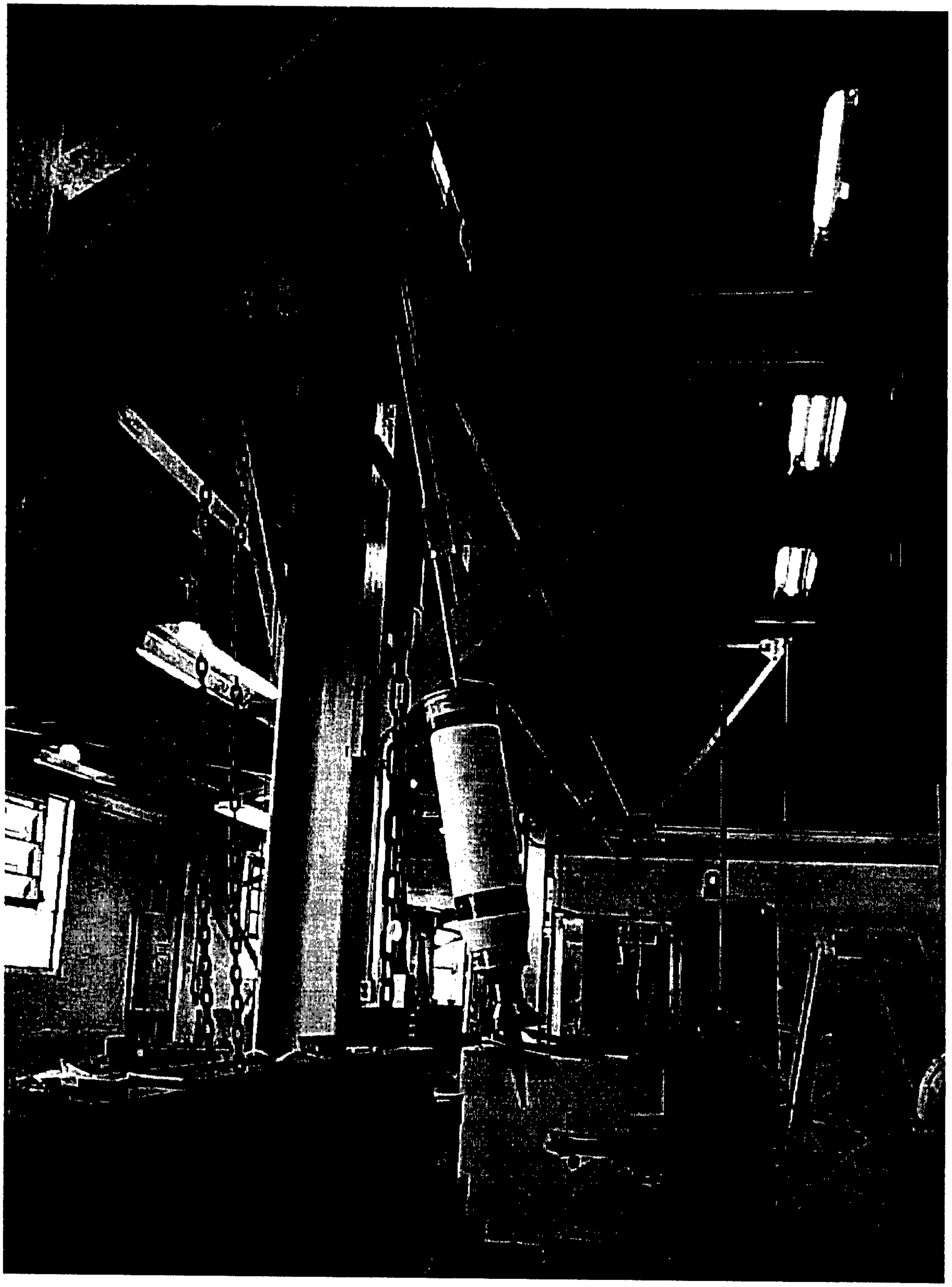

Figure 14
Pendulum test in operation

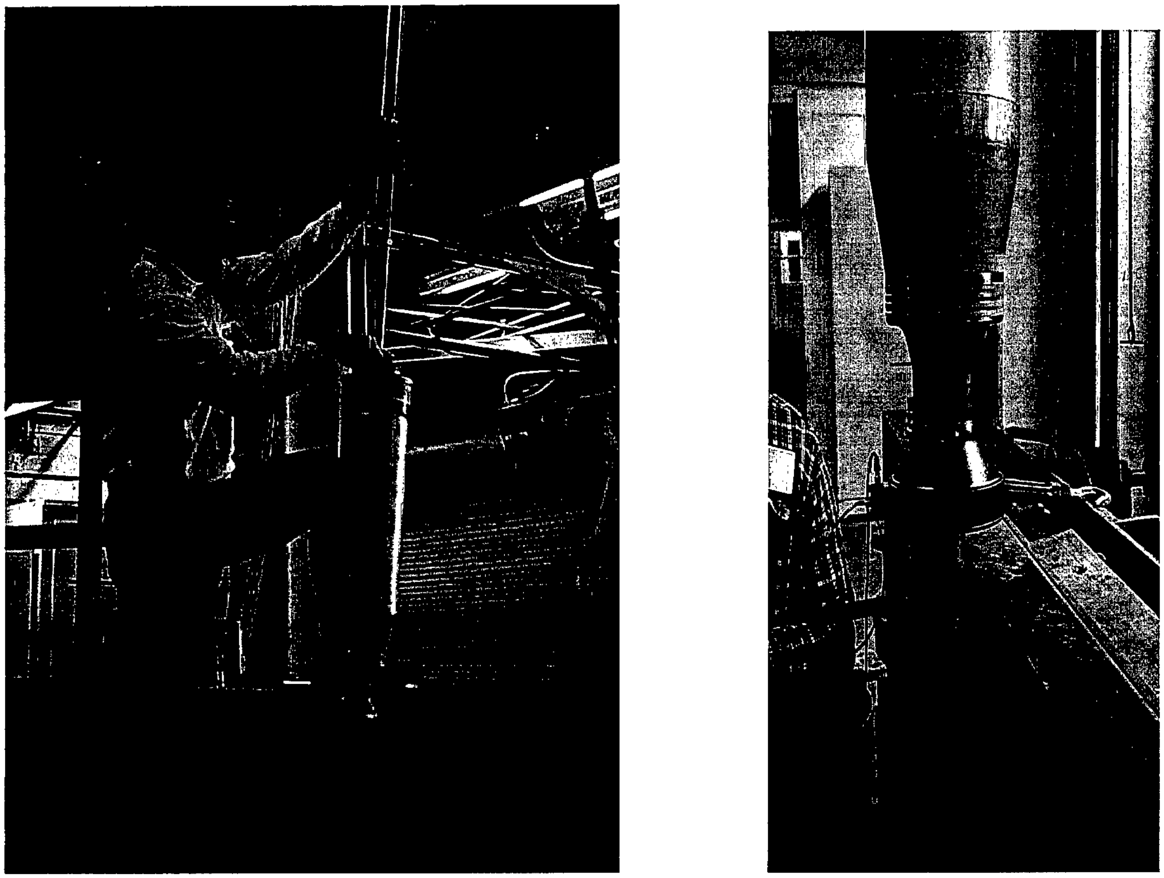

Figure 15
Pendulum test setup

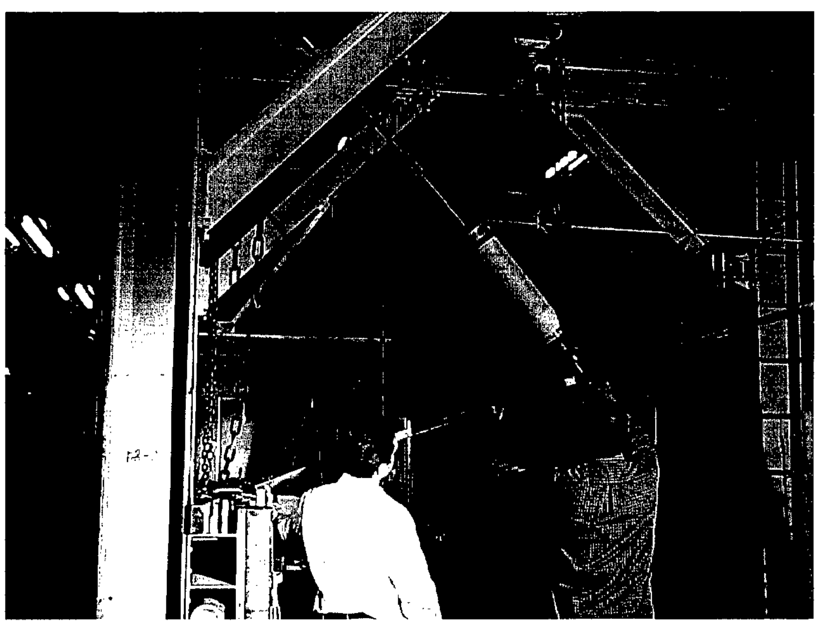

Figure 16
Pendulum test setup (2)

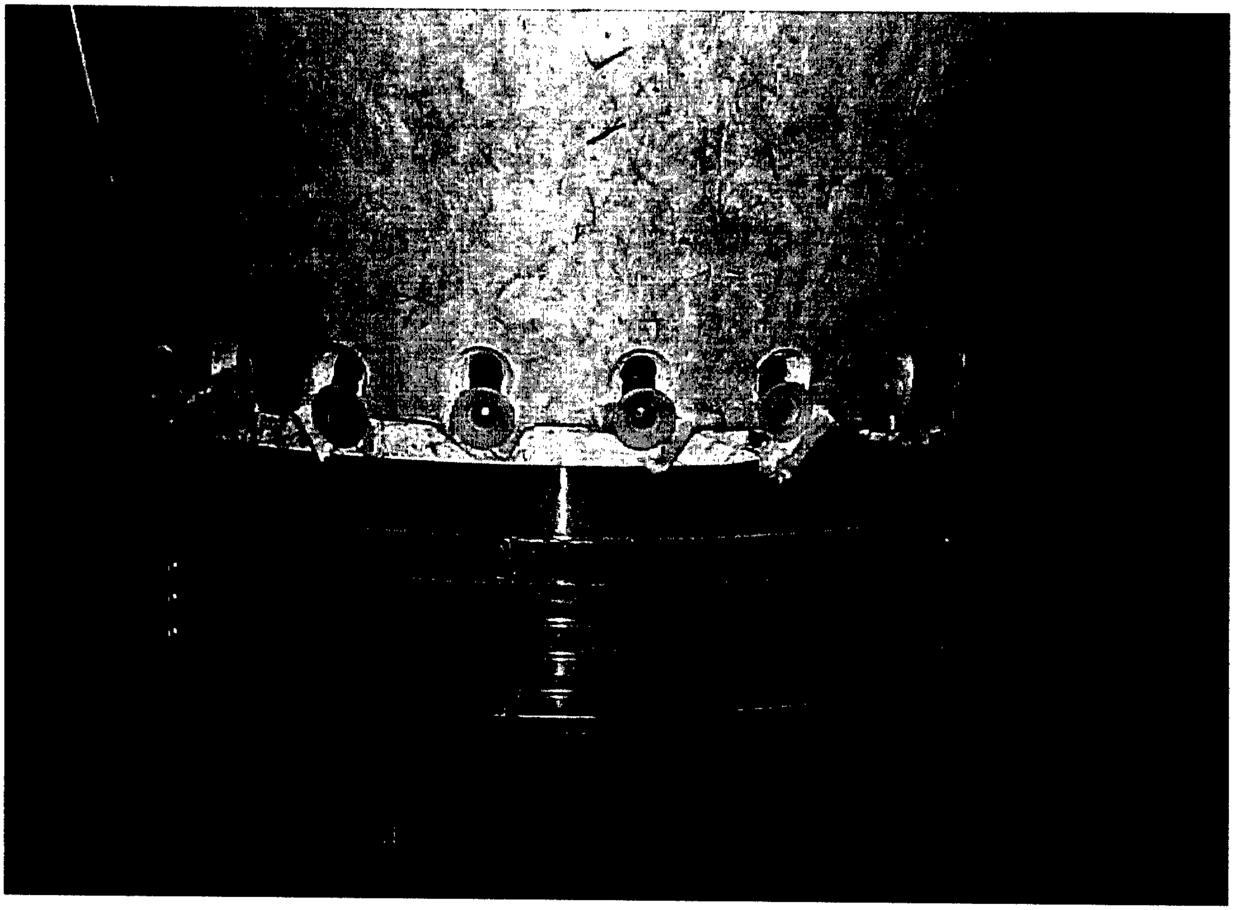

Figure 17
Pendulum test failure

Summary of Ballistic Testing for Residue at APG

as of 3/29/01

DATE	LOT	MODIFICATION/FIX	N	AMMO TEMP	TUBE	Rapid Fire?	RESULTS
12 Dec 00	ORI00H703-002A	No Mod	10	20 F (-7 C)	1146	No	No Residue
12-13 Dec 00	ORI00H703-002A	No Mod	10	-50 F (-46 C)	1146	No	No Residue
13 Dec 00	ORI00H703-002A	No Mod	10	145 F (63 C)	1146	No	No Residue
13 Dec 00	ORI00H703-002A	Double-sided adhesive on adapter	10	20 F (-7 C)	1146	No	No Residue
13 Dec 00	ORI00H703-002A	Double-sided adhesive on adapter	10	-50 F (-46 C)	1146	No	No Residue
13 Dec 00	ORI00H703-002A	Double-sided adhesive on adapter	10	145 F (63 C)	1146	No	No Residue
13 Dec 00	**ORI00H703-002A**	**No Mod**	**9**	**20 F (-7 C)**	**1146**	**Yes**	**10th Rd stuck**
8 Jan 01	ORI00H703-002A	No Mod	9	20 F (-7 C)	1146	Yes	No Residue
16 Jan 01	ORI00H703-002A	No Mod	87	20 F (-7 C)	1146	Yes	No Residue
16 Jan 01	ORI00H703-002A	No Mod	39	125 F (52 C)	1146	Yes	No Residue
16 Jan 01	ORI00H703-002A	No Mod	13	-25 F (-32 C)	1146	Yes	No Residue
17 Jan 01	ORI00H703-002A	No Mod	83	-25 F (-32 C)	1146	Yes	No Residue
17 Jan 01	ORI00H703-002A	No Mod	45	125 F (52 C)	1146	Yes	No Residue
18 Jan 01	ORI00H703-002A	No Mod	18	20 F (-7 C)	1146	Yes	No Residue
18 Jan 01	ORI00H703-002A	No Mod	9	125 F (52 C)	1146	Yes	No Residue
24 Jan 01	ORI00H703-002A	Teflon Tape Single Layer	5	70 F (21 C)	1146	Yes	No Residue
13 Mar 01	ORI00H703-002A	No Mod (Remote Firing for Safety)	3	32 F (0 C)	6385	Yes	No Residue
13 Mar 01	**ORI00H703-002A**	**No Mod (Temperature Inst Test)**	**3**	**32 F (0 C)**	**6385**	**Yes**	**4th Rd stuck**
13 Mar 01	ORI00H703-002A	No Mod (Temperature Inst Test)	8	32 F (0 C)	6385	Yes	No Residue
13 Mar 01	ORI00H703-002A	No Mod (Controls)	7	32 F (0 C)	6385	Yes	No Residue
13 Mar 01	**ORI00H703-002A**	**No Mod (Controls)**	**4**	**32 F (0 C)**	**6385**	**Yes**	**5th Rd stuck**
13 Mar 01	**ORI00H703-002A**	**No Mod (Controls)**	**2**	**32 F (0 C)**	**6385**	**Yes**	**3rd Rd stuck**
14 Mar 01	**ORI01B125-001**	**Gray Epoxy & New Gen Insert "Fix"**	**8**	**32 F (0 C)**	**6385**	**Yes**	**9th Rd stuck**
14 Mar 01	**ORI01B703-005**	**Humiseal Paint & Less Epoxy "Fix"**	**12**	**32 F (0 C)**	**6385**	**Yes**	**13th Rd stuck**
15 Mar 01	ORI01B001S270	New Gen Insert & Less Green Epoxy "Fix"	15	32 F (0 C)	6385	Yes	No Residue
15 Mar 01	ORI01B001S270	New Gen Insert & Less Green Epoxy "Fix"	15	32 F (0 C)	6385	Yes	No Residue
15 Mar 01	**ORI01B001S269**	**New Gen Insert Only "Fix"**	**9**	**32 F (0 C)**	**6385**	**Yes**	**10th Rd stuck**
15 Mar 01	ORI99G701-001B	Pop Rivet Design	15	32 F (0 C)	6385	Yes	No Residue
15 Mar 01	ORI99G701-001B	Pop Rivet Design	15	32 F (0 C)	6385	Yes	No Residue
16 Mar 01	ORI01C001S271	Nylon Wedge Ring Design "Fix"	15	32 F (0 C)	6385	Yes	No Residue
16 Mar 01	ORI01C001S271	Nylon Wedge Ring Design "Fix"	15	32 F (0 C)	6385	Yes	No Residue
16 Mar 01	**ORI00H703-002A**	**No Mod (Controls)**	**4**	**32 F (0 C)**	**6385**	**Yes**	**5th Rd stuck**
16 Mar 01	ORI01C001S271	Nylon Wedge Ring Design "Fix"	10	32 F (0 C)	6385	Yes	No Residue
20 Mar 01	ORI99G701-001B	Pop Rivet Design	15	32 F (0 C)	6385	Yes	No Residue
20 Mar 01	ORI99G701-001B	Pop Rivet Design	5	32 F (0 C)	6385	Yes	No Residue
20 Mar 01	ORI01B001S270	New Gen Insert & Less Green Epoxy "Fix"	15	32 F (0 C)	6385	Yes	No Residue
20 Mar 01	ORI01B001S270	New Gen Insert & Less Green Epoxy "Fix"	5	32 F (0 C)	6385	Yes	No Residue
20 Mar 01	ORI00H703-002A	Controls with Triple Teflon Tape on Adapter	10	32 F (0 C)	6385	Yes	No Residue
20 Mar 01	ORI00H703-002A	No Mod (Controls)	15	32 F (0 C)	6385	Yes	No Residue
20 Mar 01	**ORI00H703-002A**	**No Mod (Controls)**	**4**	**32 F (0 C)**	**6385**	**Yes**	**5th Rd stuck**
29 Mar 01	ORI99B700-001B	Bolt-on Cover Design with Epoxy Paint	15	32F (0C)	6385	No	No Residue
29 Mar 01	**ORI99B700-001B**	**Bolt-on Cover Design with Epoxy Paint**	**11**	**32F (0C)**	**6385**	**No**	**12th Rd stuck**
29 Mar 01	ORI99B700-001B	Bolt-on Cover Design with Epoxy Paint	15	32F (0C)	6385	No	No Residue
29 Mar 01	ORI99B700-001B	Bolt-on Cover Design with Epoxy Paint	4	32F (0C)	6385	No	No Residue

Figure 18
Rapid fire residue test for pop-rivet design (from tank)

STATIONARY USER TEST WITH M865 (4 MODS) AT APG 3/7/2001

LOT	DESIGN	LOADER	EVENT	TANK HATCHES TC	TANK HATCHES Loader	ANOMALIES/NOTES
125-001	Optimum Epoxy New IC	SSG Baker	3 Power Loads (1 rd)	Closed	Open	
		SFC Gross	3 Power Loads (1 rd)	Closed	Open	
		SSG Miller	3 Power Loads (1 rd)	Closed	Open	
		SSG Miller	"Bend" removing from Ready Rack Bang Tip on Strut Support Bang Cartridge/Projectile on Breech Bang Projectile on Loader's Tray	Closed	Open	
		SSG Baker	"Bend" removing from Ready Rack Bang Tip on Strut Support Bang Cartridge/Projectile on Breech Bang Projectile on Loader's Tray	Closed	Open	
		SFC Gross	"Bend" removing from Ready Rack Bang Tip on Strut Support Bang Cartridge/Projectile on Breech Bang Projectile on Loader's Tray	Closed	Open	
701-1B	Pop Rivet Fix	SSG Baker	3 Power Loads (1 rd)	Closed	Open	
		SFC Gross	3 Power Loads (1 rd)	Closed	Open	
		SSG Miller	3 Power Loads (1 rd)	Closed	Open	
		SSG Miller	"Bend" removing from Ready Rack Bang Tip on Strut Support Bang Cartridge/Projectile on Breech Bang Projectile on Loader's Tray	Closed	Open	
		SSG Baker	"Bend" removing from Ready Rack Bang Tip on Strut Support Bang Cartridge/Projectile on Breech Bang Projectile on Loader's Tray	Closed	Open	
		SFC Gross	"Bend" removing from Ready Rack Bang Tip on Strut Support Bang Cartridge/Projectile on Breech Bang Projectile on Loader's Tray	Closed	Open	MOPP Mask Worn by Loader MOPP Mask Worn by Loader MOPP Mask Worn by Loader MOPP Mask Worn by Loader

Figure 19
Stationary users test

CLAIMS NOT INCLUDED

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Table 1
M865E3 pop rivet secured cargo vibration test: summary of dispersion, velocity, and pressure data – 03 December

Date Fired 2001	Test round number	Round type	Cond. Temp (°C)	N	Boresight & wind corrected Target impact dispersion, mils 1000 m Hor	1000 m Ver	2500 m Hor	2500 m Ver	DOF 2500 m Hor	DOF 2500 m Ver	Muzzle (mps) Mean	Muzzle (mps) SD	Mean falloff velocity (m/s) 0 – 1000	1000– 2500	2000– 3000	FO avg	Chamber pressure (bars) Rear Mean	Rear SD	Forward Mean	Forward SD	Mean T4 time (ms)
3 Dec	1-3	Spotter	-32	3	0.58	0.38	0.46	0.38			1618.2	29.84	307.5	319.5	0	313.5	4408	88.6	4149	103.4	21
3 Dec	4-8	Control	-32	5	0.37	0.34	0.36	0.35			1637.5	3.37	327.9	319.5	0	323.7	4380	41.6	4183	31.8	22
3 Dec	9-10	Spotter	-32	2	0.22	0.48	0.09	0.55			1633.1	16.26	318.8	318.3	0	318.5	4456	62.9	4226	5.0	21
3 Dec	11-15	SCV	-32	5	0.23	0.23	0.27	0.26			1614.1	4.77	329.6	316.4	0	323.0	4110	23.2	3925	27.5	32
3 Dec	16-20	SCV	-32	5	0.24	0.36	0.23	0.36			1610.5	3.74	327.8	316.8	0	322.3	4075	44.4	3899	37.7	26
3 Dec	21-25	Control	-32	5	0.38	0.42	0.29	0.44			1642.4	5.96	325.7	318.7	0	322.2	4378	49.7	4203	39.0	21
		Pooled test		15	0.21	0.28	0.24	0.30			1612.2	5.31	329.7	316.5	0	323.1	4077	51.7	3897	46.7	28
		DOF applied					0.20	0.26													

Table 2
M865E3 pop rivet secured cargo vibration test: summary of dispersion, velocity, and pressure data – 04 December

Date Fired 2001	Test round number	Round type	Cond. Temp (°C)	N	Boresight & wind corrected Target impact dispersion, mils 1000 m Hor	1000 m Ver	2500 m Hor	2500 m Ver	DOF 2500 m Hor	DOF 2500 m Ver	Muzzle (mps) Mean	Muzzle (mps) SD	Mean falloff velocity (m/s) 0 – 1000	1000– 2500	2000– 3000	FO avg	Chamber pressure (bars) Rear Mean	Rear SD	Forward Mean	Forward SD	Mean T4 time (ms)
4 Dec	31-35	Control	52	5	0.15	0.29	0.14	0.28			1726.8	4.18	334.4	322.4	0	328.4	5072	71.7	4944	81.3	13
4 Dec	36-40	SCV	52	5	0.09	0.20	0.06	0.23			1724.2	5.11	335.9	322.2	0	329.0	4906	28.2	4752	29.8	12
4 Dec	41-44	SCV	52	4	0.20	0.09	0.22	0.09			1721.3	1.67	332.7	320.7	0	326.7	4907	24.7	4742	22.8	13
		Pooled test		9	0.14	0.16	0.15	0.18			1722.9	4.01	334.5	321.5	0	328.0	4906	26.8	4748	27.0	12
		DOF applied					0.13	0.16													

Table 3

M865E3 pop rivet sequential rough handling and secured cargo vibration tests: summary of dispersion, velocity, and pressure data – 05 December

Date Fired 2001	Test round number	Round type	Cond. Temp (°C)	N	Boresight & wind corrected: Target impact dispersion, mils 1000 m Hor	Ver	2500 m Hor	Ver	DOF 2500 m Hor	Ver	Muzzle (mps) Mean	SD	Mean falloff velocity (m/s) 0 – 1000	1000– 2500	2000– 3000	FO avg	Chamber pressure (bars) Rear Mean	SD	Forward Mean	SD	Mean T4 time (ms)
5 Dec	45-49	Control	52	5	0.31	0.23	0.27	0.27			1721.3	4.39	333.1	321.8	0	327.4	5072	34.8	4889	42.7	13
5 Dec	50-55	SCV	52	6	0.21	0.10	0.19	0.14			1720.8	2.85	332.5	321.3	0	326.9	4928	35.7	4743	38.7	13
5 Dec	56-60	SCV	52	5	0.03	0.14	0.05	0.16			1735.3	2.72	331.7	321.0	0	326.3	5095	38.8	4923	34.3	12
5 Dec	61-65	SCV	52	5	0.18	0.15	0.14	0.15			1734.8	0.90	329.9	320.8	0	325.3	5111	32.3	4948	42.5	11
5 Dec	66-71	SCV	52	5	0.22	0.15	0.07	0.25			1739.1	4.64	333.2	319.5	0	326.4	5115	64.6	4943	68.8	8
		Pooled test		21	0.18	0.13	0.13	0.18			1731.4	3.03	331.9	320.7	0	326.3	5056	44.2	4882	47.5	11
		DOF applied					0.11	0.18													
5 Dec	72-81	SRH	52	5	0.11	0.10	0.18	0.11			1730.1	5.14	328.5	317.3	0	324.8	5066	48.6	4870	52.0	12
5 Dec	77-81	SRH	52	5	0.17	0.03	0.08	0.03			1731.5	3.66	328.1	317.5	0	322.8	5065	22.3	4878	10.4	12
5 Dec	82-86	SRH	52	5	0.03	0.15	0.11	0.17			1733.9	1.89	330.0	318.5	0	324.2	5077	33.5	4876	37.5	12
		Pooled test		15	0.12	0.10	0.13	0.12			1731.8	3.81	328.9	317.8	0	323.9	5069	36.4	4875	37.5	12
		DOF applied					0.11	0.10													

Table 4

M865E3 pop rivet sequential rough handling and secured cargo vibration tests: summary of dispersion, velocity, and pressure data – 06 December

Date Fired 2001	Test round number	Round type	Cond. Temp (°C)	N	Boresight & wind corrected: Target impact dispersion, mils 1000 m Hor	Ver	2500 m Hor	Ver	DOF 2500 m Hor	Ver	Muzzle (mps) Mean	SD	Mean falloff velocity (m/s) 0 – 1000	1000– 2500	2000– 3000	FO avg	Chamber pressure (bars) Rear Mean	SD	Forward Mean	SD	Mean T4 time (ms)
6 Dec	87-91	Control	52	5	0.15	0.25	0.16	0.26			1721.5	5.81	328.0	318.3	0	323.1	5089	75.2	4895	65.2	13
6 Dec	92-96	SRH	52	5	0.20	0.15	0.16	0.13			1728.0	3.34	327.0	317.1	0	322.1	5078	30.4	4874	35.3	12
6 Dec	97-101	SRH	52	5	0.09	0.18	0.10	0.17			1727.6	4.14	326.8	316.9	0	321.8	5020	23.6	4819	41.3	12
6 Dec	102-106	SRH	52	5	0.12	0.10	0.11	0.08			1727.7	5.44	325.8	317.1	0	321.4	5063	40.3	4851	40.9	12
		Pooled test		15	0.14	0.14	0.13	0.13			1727.8	4.39	326.5	317.0	0	321.8	5054	34.7	4848	39.2	12
		DOF applied					0.11	0.11													
6 Dec	108-112	Control	-32	5	0.42	0.30	0.42	0.33			1635.9	2.11	320.1	311.4	0	315.8	4355	29.6	4140	19.9	21
6 Dec	113-117	SCV	-32	5	0.23	0.33	0.17	0.35			1611.6	5.93	320.5	309.9	0	315.2	4066	55.0	3869	46.0	26
6 Dec	118-122	SCV	-32	5	0.33	0.20	0.32	0.20			1615.0	6.11	320.6	308.7	0	314.7	4115	47.0	3900	36.5	28
6 Dec	123-126	SCV	-32	4	0.45	0.36	0.35	0.32			1612.2	6.07	323.9	308.1	0	316.0	4085	86.7	3872	71.4	22
		Pooled test		14	0.34	0.30	0.28	0.29			1613.0	6.03	321.3	309.0	0	315.2	4089	62.9	3881	51.4	25
		DOF applied					0.24	0.25													

Table 5
M865E3 pop rivet sequential rough handling test: summary of dispersion, velocity, and pressure data – 07 December

Date Fired 2001	Test round number	Round type	Cond. Temp (°C)	N	Boresight & wind corrected: Target impact dispersion, mils, 1000 m		Target impact dispersion, mils, 2500 m		DOF 2500 m		Muzzle (mps)		Mean falloff velocity (m/s)				Chamber pressure (bars): Rear		Forward		Mean T4 time (ms)
					Hor	Ver	Hor	Ver	Hor	Ver	Mean	SD	0 – 1000	1000– 2500	2000– 3000	FO avg	Mean	SD	Mean	SD	
7 Dec	129-133	Control	-32	5	0.28	0.45	0.29	0.49			1638.0	2.83	323.0	313.1	0	318.0	4372	30.9	4098	30.7	22
7 Dec	134-138	SHR	-32	5	0.24	0.41	0.26	0.45			1612.8	4.29	325.5	310.8	0	318.1	4074	29.6	3843	23.7	22
7 Dec	139-143	SHR	-32	5	0.21	0.19	0.21	0.20			1612.4	4.33	325.1	311.2	0	318.1	4054	43.2	3843	23.9	25
7 Dec	144-148	SHR	-32	5	0.55	0.31	0.55	0.27			1612.2	6.78	324.8	311.0	0	317.9	4060	75.6	3856	65.3	23
7 Dec	149-153	SHR	-32	5	0.40	0.29	0.42	0.33			1612.7	7.51	325.4	311.0	0	318.2	4046	86.1	3832	71.0	26
7 Dec	154-158	SRH	-32	5	0.14	0.12	0.16	0.15			1610.7	4.34	325.4	311.6	0	318.5	4027	26.7	3817	28.8	24
7 Dec	159-163	SRH	-32	5	0.30	0.15	0.21	0.20			1615.6	5.38	324.6	310.6	0	317.6	4089	47.4	3874	35.2	23
		Pooled test		30	0.33	0.26	0.33	0.28			1612.7	5.59		311.0	0	318.1	4058	56.0	3844	46.6	24
		DOF applied					0.29	0.25													

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